学　位　論　文　要　旨

Study on Optimal Conditions of Freeze Drying Operation for Preserving Qualities of Blueberries
ブルーベリーの品質保持に適する真空凍結乾燥法の操作条件に関する研究

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Fundamental human needs for healthy foods are increasing in the world. Blueberries are popular in both demand and production because of high nutrients, especially, the source of antioxidants in addition to the taste advantage. Along with the rapid growth of demands, there is a shortage of processing technologies that extend shelf life so as to retain the original nutrients and flavors of the product. The freeze drying preserving nutrient as well as flavors has played an increasingly important role in the production of dried foods. In this research, optimal conditions of the prior-freezing and vacuum drying operations for whole blueberry fruits were studied in relation to preserving qualities of the final products. In chapter 1, these backgrounds and aims of research were mentioned with reviews of previous studies on drying blueberries.

In chapter 2, the cooling condition of the prior-freezing operation was discuss in relations between the freezing characteristics of blueberries and some typical physicochemical properties. Blueberries harvested in the university orchard were frozen at four different freezing speed by setting the cooling temperatures at -20, -40, -60 and -80 ºC in a deep freezer. As results, icing time of blueberries depended on their own size, mass and the cooling temperature. The icing time increased proportionally with increasing size and mass of the fruit, while the thermal diffusivities increased gradually with size and mass. The cooling temperature affected significantly the freezing point, icing time and ice crystal size. The phase of blueberries was changed from liquid to solid at a lower cooling temperature more quickly. For the diameter of 18 mm of Tifblue fruit, the required icing time were 33.1, 15.2, 11.2 and 9.0 minutes at the cooling temperature of -20, -40, -60 and -80 ºC, respectively. The higher freezing speed also created smaller ice crystals in blueberries so that may cause the big changes in the quality of freeze-dried products.

In chapter 3, the drying characteristics of blueberries was studied in relation to the supplying heat flux conditions in the vacuum drying process. The heat flux was controlled at four different levels of 0, 100, 225 and 400 W/m^2 by adjusting heater power. As experimental results, the drying time and the drying rate were strongly influenced by the supplying heat flux in the vacuum drying process. Under high heat flux of 400 W/m^2, the drying rate was high for the initial four hours and reached the stable mass soon compared with other lower heat flux conditions. The total drying time decreased by 30% when heat flux of 400 W/m^2 was used as a substitute of 0 W/m^2. The freezing speed constituted the difference in nucleation temperature which influenced the drying time during the sublimation process. Blueberries frozen at higher freezing speed had a lower nucleation temperature, which led to the increase in the sublimation time and caused the increase in total drying time. On the other hand, large ice crystals formed at lower freezing speed led to large volumetric shrinkage and dense freeze-dried blueberries resulting in darker skin color.

In chapter 4, the influences of operation conditions in the freeze drying process were investigated on the change in qualities. The nutrition loss including aroma, sugar content, anthocyanin of dried blueberries as well as the change in the internal structure of fruits were measured under the different freeze-drying conditions. GC-MS, HPLC and spectrophotometer instruments were applied to analyze volatile compounds, organic acid, sugar content and anthocyanin of blueberries and internal structure of a dried fruit was analyzed with the micro-focus X-ray CT system. As the results, the operation condition of freezing drying process influenced on the quality of freeze-dried products, especially their aroma, anthocyanin, sugar content, ascorbic acid and internal structure. Aroma, and anthocyanin content decreased significantly according to the lower freezing speed and the higher supplying heat flux. More than 50 s volatile compounds were detected in Dixi under the cooling temperature of 20 ºC (at 0.47 mm/min in freezing speed) in the prior freezing process, while the number of volatile compounds decreased to 40 s, 30 s, and 20 s at the cooling temperature of -40 ºC (0.94 mm/min), -60 ºC (1.26 mm/min), and -80 ºC (1.54 mm/min), respectively, in accordance with the increase in the freezing speed. Some main aroma volatile compound of blueberries such as acetic acid, furfural, 2-hexanol, 3-hexanol were found in the trapped vapor under the conditions of cooling temperature at -20 ºC and heat flux at 400 W/m^2, however not appear under the conditions of lower cooling temperature and lower heat flux. The organic acid of dried blueberries decreased significantly by 60 % in the condition of higher heat flux, while no influence of freezing speed was detected. The pores in dried blueberries diminished in size and an amount of damaged tissues decreased according to the higher freezing speed in the prior freezing.

In chapter 5, researches were concluded that blueberries could be dried with the freeze drying in high qualities by selecting the proper cooling temperature and supplying heat flux. The freezing speed was one of main factors that influenced qualities of dried products directly because of ice crystal size formed in the freezing operation. Higher heat flux contributed to reduce the drying time significantly. Since the supplying heat flux needs much energy, further study on the effects of mechanical pre-treatment to blueberry skin is suggested to obtain the

reasonable economic conditions of the prior freeze drying process for drying blueberries.